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# Autonomous Platform Demonstrator

**Army Science Conference**
**29 NOV – 03 DEC 2010**

**U.S. Army RDECOM – TARDEC**

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# Autonomous Platform Demonstrator (APD)

Thermal and Power Management Systems

**ARV SFR Requirements**

Series Hybrid Electric Drive

Suspension and Hub Motor Technology

**Key Performance Parameter is 80 KPH!**

UGV Safety System

## Autonomous Platform Demonstrator (APD)

Purpose:

- This platform demonstrator has developed, integrated and tested next generation Unmanned Ground Vehicle (UGV) mobility technologies such as hybrid electric drive systems, advanced suspension systems, thermal management systems, and UGV safety systems. It is capable of reaching speeds up to 50 miles per hour and performing maneuvers at those speeds.

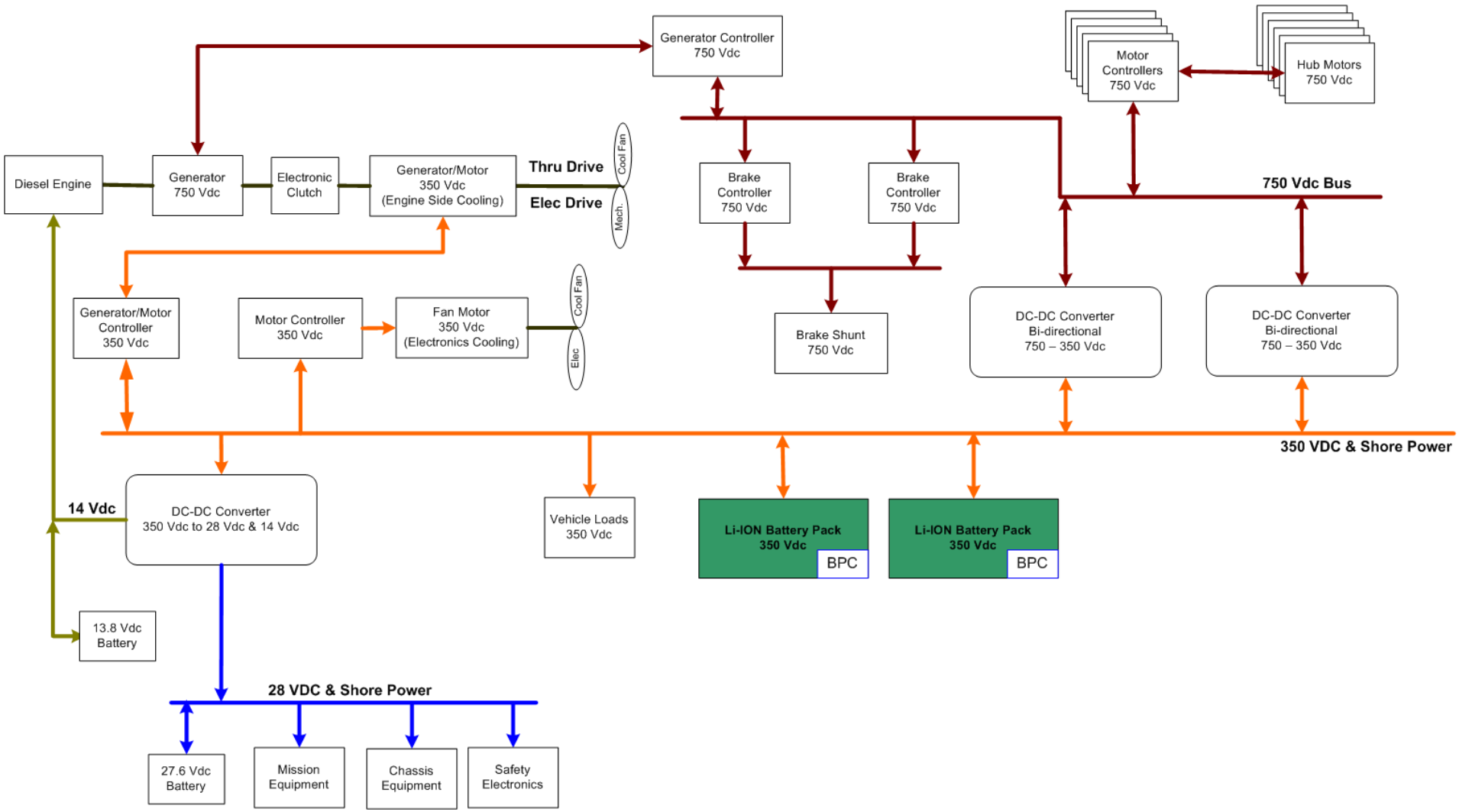
- The APD is *the* integration platform for the Robotic Vehicle Control Architecture (RVCA) and Safe Operations of Unmanned Systems for Reconnaissance in Complex Environments (SOURCE) Army Technology Objectives (ATO).

Status/Technology Readiness Level :

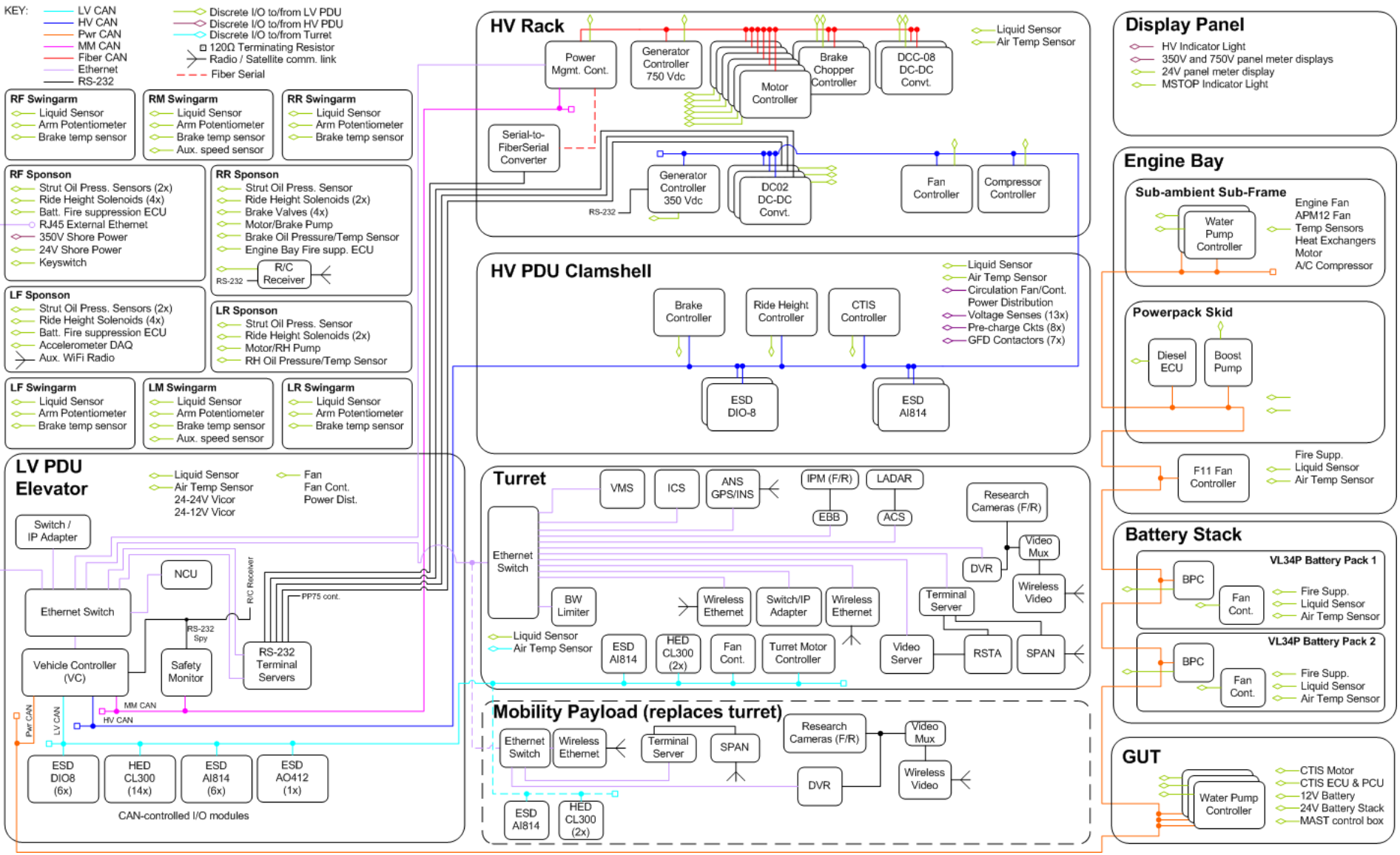
- The vehicle achieved first drive in early August 2009 and has logged over 4300 kilometers since. The APD underwent an intensive schedule of developmental and mobility testing tightly coupled with experimentation for the RVCA ATO. Testing has culminated with a Soldier Operational Exercise 2.0 conducted in the 4th quarter of Fiscal Year 10 at Fort Hood.
- Current Technology Readiness Level is 6.

| APD Specifications | Goal | Unit |
|---|---|---|
| Acceleration (0-30 MPH) | 10.5 | sec |
| Max Speed (Hardball) | 50 | mph |
| Max Speed (Cross Country) | 28 | mph |
| Generator Output | 197 | hp |
| Fuel | JP8, Diesel | |
| Battery Energy | 21.8 | kW-hr |
| Battery Max Power | 282 | hp |
| Traction Motor Power | 1,046 | hp |
| Power/Weight Ratio | 112 | hp/ton |
| Peak Torque (Sum 6 Wheel Drive) | 41,368 | ft-lb |
| Steering Radius | 0 | in |
| Vertical Obstacle | 39 | in |
| Trench | 39 | in |
| V-Ditch | 108 | in |
| Ground Clearance | 4-25 | in |
| Side Slope | 30 | % |
| Longitudinal Slope | 60 | % |
| Fording | 20 | in |
| Gross Vehicle Weight | 9.3 | ton |
| Normal Operating Height | 87 | in |
| Minimum Crouched Height | 76 | in |
| Overall Length | 182 | in |
| Overall Width | 98 | in |
| Operating Temperatures | -4 to 113 | °F |
| Available Direct Current Voltages | 750, 350, 28 VDC | |
| Standby Power Available (Genset and Batteries) | | |
| Mechanical Redundancy (6WD, Battery and/or Engine Power) | | |

# APD Hybrid-Electric Architecture



# APD System View - 1

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# APD Safety System

## ***Objective*:**

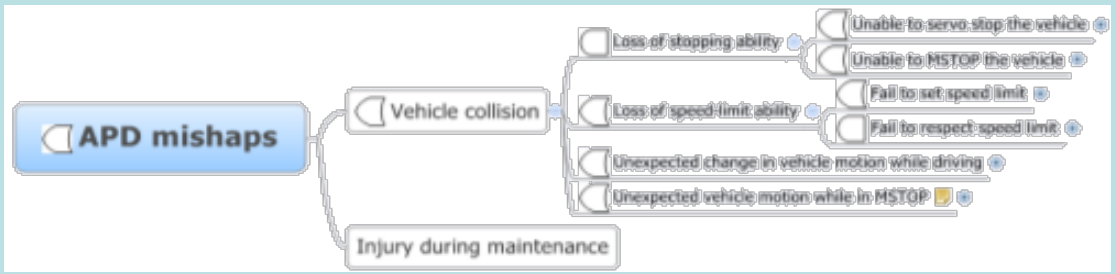
- Enforce and control safe standoff distance between APD and nearby personnel

## ***Approach*:**

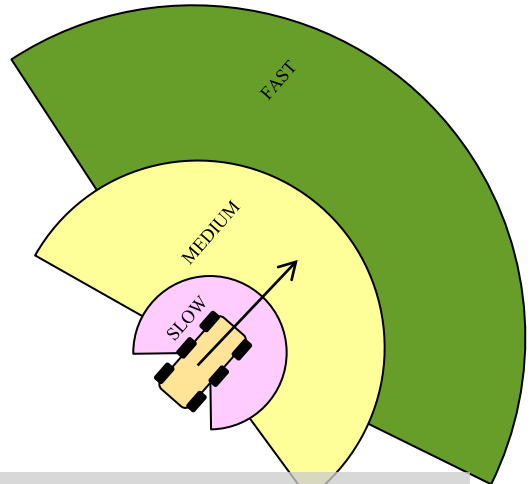
- Provide fail-safe braking mechanisms with well-modeled stopping distance.
- Incorporate *Safety Monitor* for redundant, high-reliability means of restraining vehicle speed.
- Identify and mitigate risks that could lead to failures of braking and speed-limiting.

## ***Techniques:***

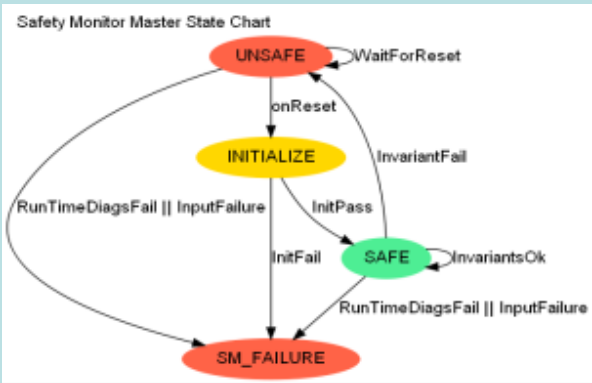
- Identifying hazards that lead to safety mishaps.
- Modeling of correlation between latent hazards with rich instrumentation.
- Firewalling safety-criticality to a subset of vehicle components.
- Developing & testing fault-resistant software for speed limiting.
- V&V testing traced to safety requirements.
- Well structured Safety Program IPT




***Careful analysis of mishaps drives safety system design***




***Reliable speed limiting allows safe standoff distances to be decreased***




***Safety Monitor ensures that safety invariants are maintained***

# APD Mobility Controller

## ***Objective***:

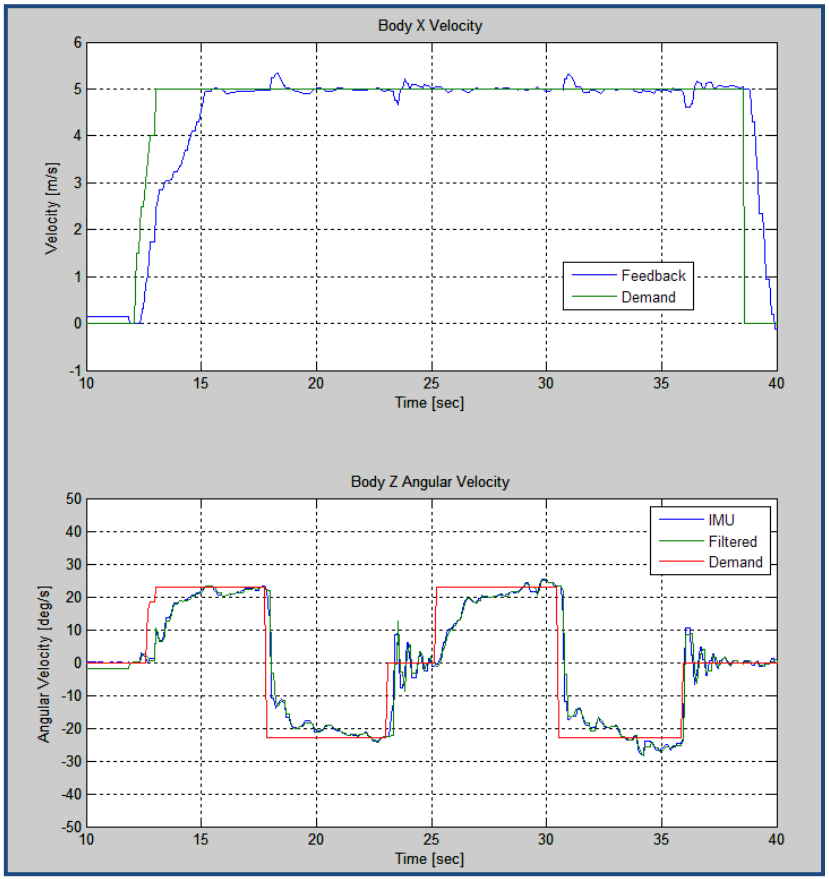
- Create a real-time vehicle controller that exploits the vehicle's independent drives and adjustable suspension for good high speed, on-road performance as well as low-speed, off road performance.

## ***Goals***:

- Stable and controllable under all conditions.
- Handle smooth and discontinuous demands.
- Optimal performance with turning prioritized higher than velocity control.
- Robust to external disturbances.
- Terrain surface friction estimation.
- Adaptive control system.
- Built-in near roll-over detection and compensation.
- Failsafe operation in case of sensor malfunction.

## ***Approach:***

- Develop detailed models in physics based simulation program.
- Calibrate models with existing vehicle data.
- Develop controller and convert to C-code
- Create automated test routines within physics based simulation program.




***Velocity and Yaw Command Tracking***

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# Thermal Management

***Objective*:**

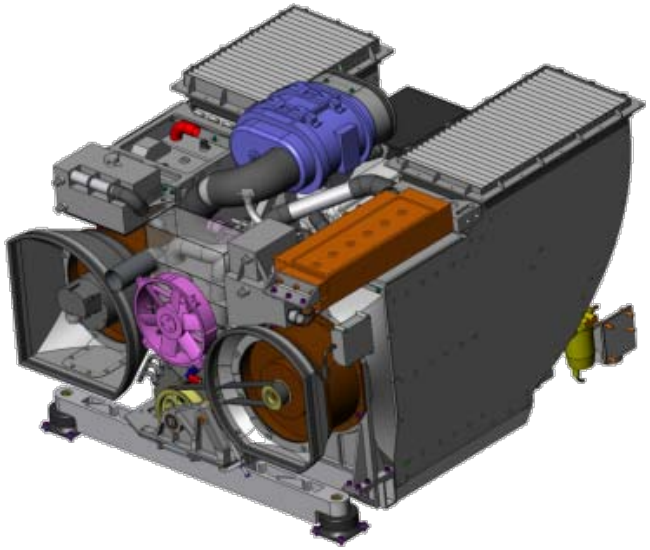
- Reliably operate APD in high thermal environments

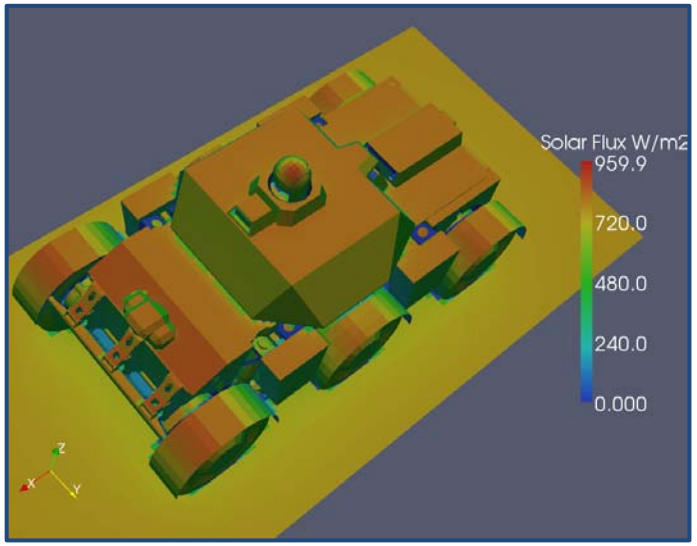
***Goals*:**

- Provide enough cooling to operate at 80 kph in 45°C
- Provide cooling for ancillary payloads as well
- Minimize volume and weight of cooling system

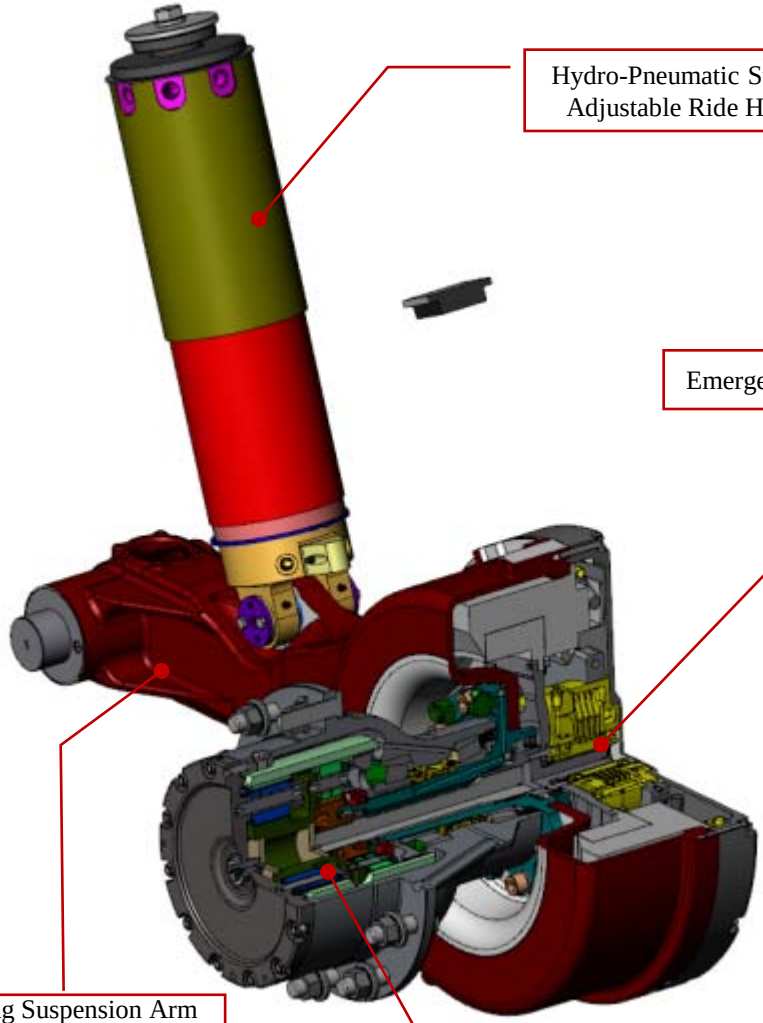
***Approach:***

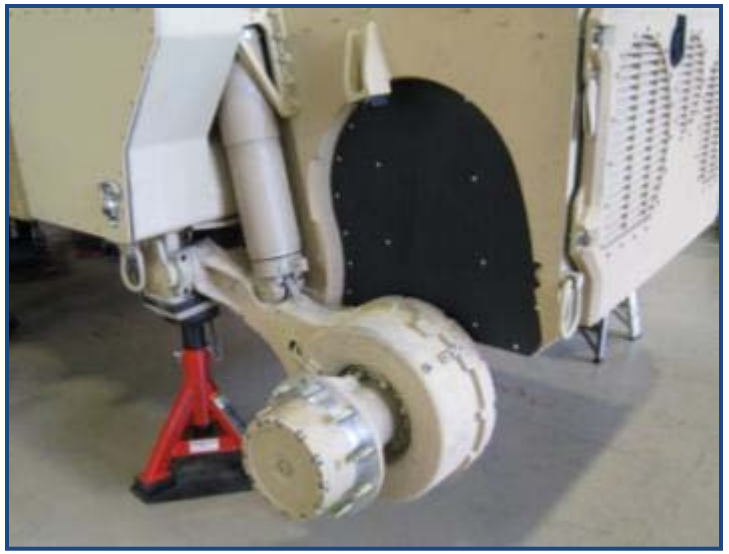
- Minimize cooling loops on the vehicle
- Re-rate components on vehicle to meet lower loop count
- Dual heat exchanger paths to split cooling load
- Model the thermal load using CFD and Solar loading
- Test components early in APD System Integration Lab
- Conduct thermal load test of vehicle in a Chassis Dynamometer Cell





# Advanced Suspension



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# APD System Integration Lab (SIL)

Fully enclosed, sound-proof engine cell
Provides safe, full power (190kW) testing of engine-generator stack

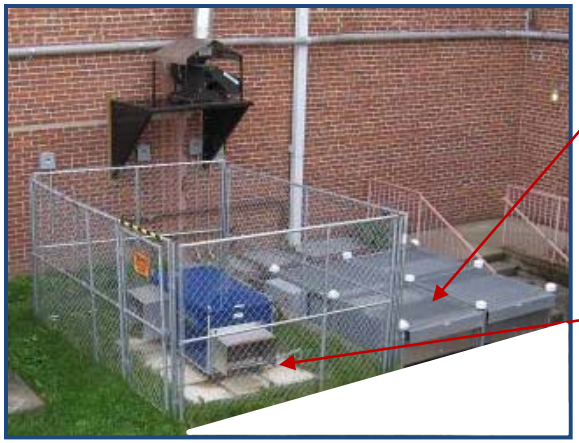
High Voltage and Low Voltage component rack
All motor, generator, & brake shunt controllers; DCDC converters

Back to Back – Motor & Hub test stands
Provides safe, full power testing of motors/hubs

Power Processing System
Provides source/sink backbone for SIL

Battery Test Cell
Provides safe, heavy load testing of batteries

Insulated, Thermal Chamber
Provides safe room for 45C full load powerpack testing



450kW Dry Cooler
Provides full cooling for engine and all hybrid components

150kW Load Resistor
Provides easy sink for 750V excess power

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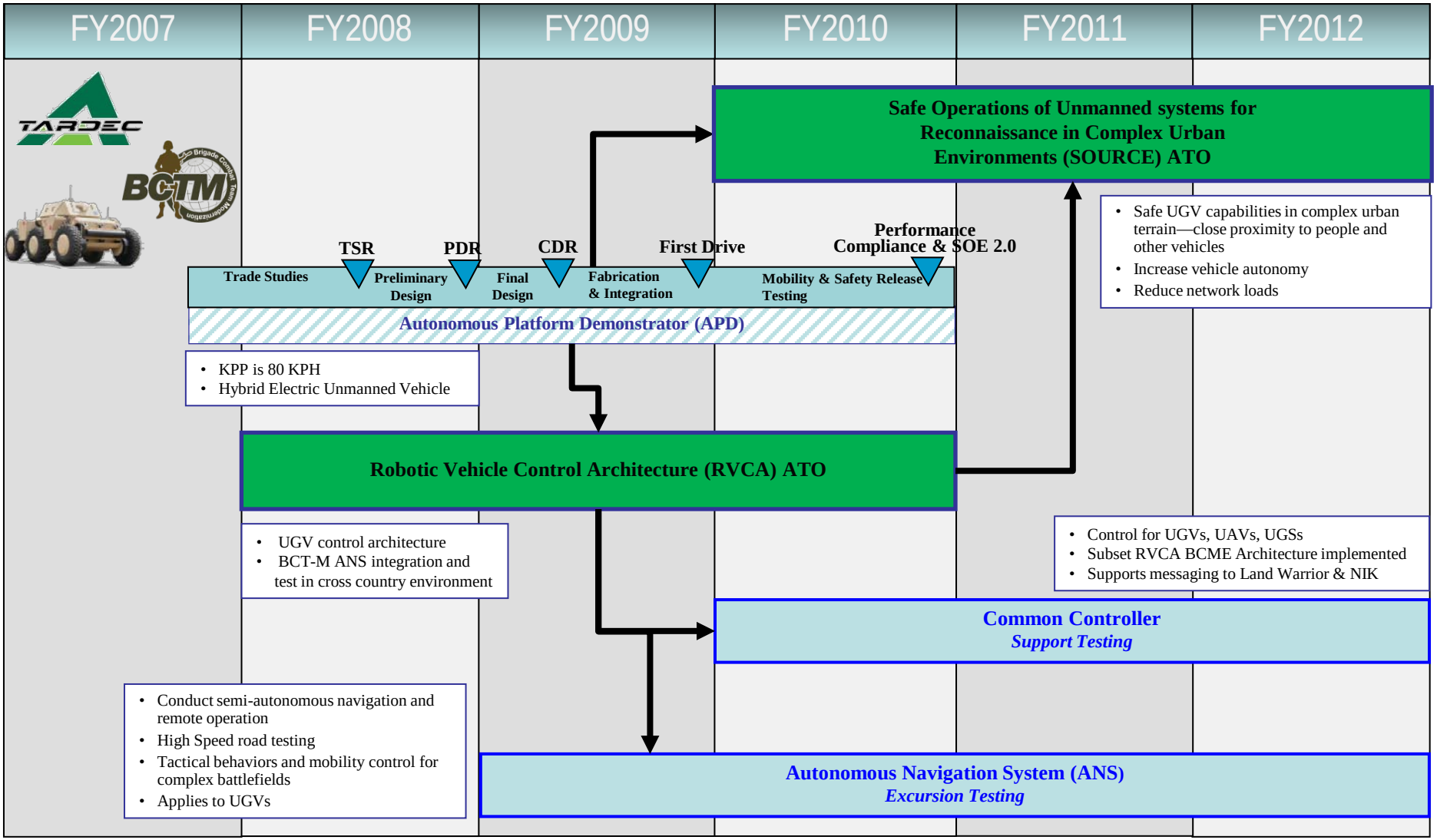
# APD Program Tie-Ins

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